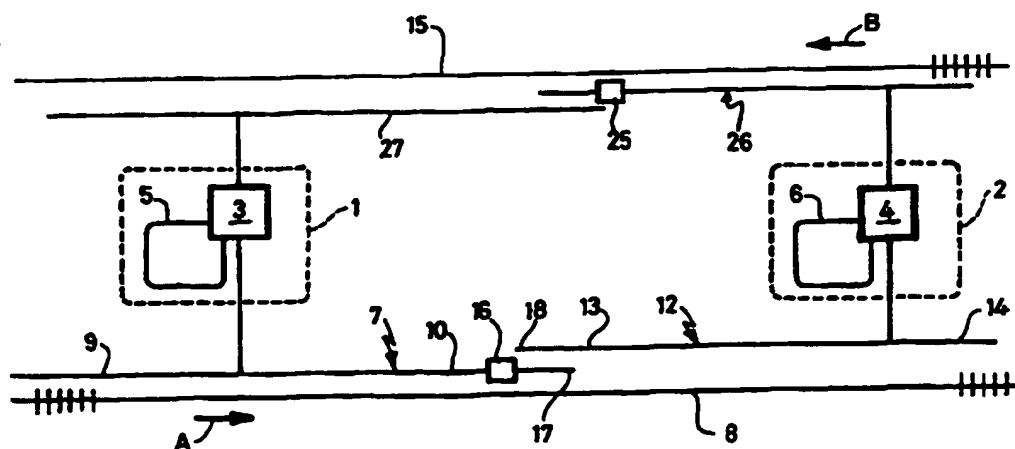


PCTWORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04B 5/00	A1	(11) International Publication Number: WO 97/16892 (43) International Publication Date: 9 May 1997 (09.05.97)
(21) International Application Number: PCT/GB96/02590 (22) International Filing Date: 22 October 1996 (22.10.96) (30) Priority Data: 9522348.3 1 November 1995 (01.11.95) GB (71) Applicant (for all designated States except US): NOKIA TELECOMMUNICATIONS OY (FI/FT); Upseerinkatu 1, P.O. Box 44, FIN-02601 Espoo (FI). (72) Inventor; and (75) Inventor/Applicant (for US only): LOWDON, Christopher, John [GB/GB]; 28 Percheron Close, Impington, Cambridge CB3 0NR (GB). (74) Agent: MORTON, Colin, David; Keith W. Nash & Co., 90-92 Regent Street, Cambridge CB2 1DP (GB).		(81) Designated States: AL, AM, AT, AU, AZ, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i>

(54) Title: METHOD AND APPARATUS FOR RADIO TELEPHONE CALL HANDOVER IN AN UNDERGROUND RAILWAY COMMUNICATIONS SYSTEM

**(57) Abstract**

Radio telephone apparatus for use in an underground railway system comprises two base stations (3, 4) respectively located at successive railway stations (1, 2). The base station (3) feeds a radiating cable (7) extending in the tunnel bore towards the base station (4) which feeds a radiating cable (12) extending in the tunnel bore towards the base station (3). When a train travels from the station (1) to the station (2), the mobile radio on the train effects call handover, i.e. transference of communication with cable (7) to communication with cable (12). To ensure no interruption in a call during handover, an attenuator (16) is incorporated in the cable (7) adjacent its end, such that the mobile radio effects call handover to the cable (12) before losing communication with the cable (7), even at the maximum possible speed of the train.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AM	Armenia	GB	United Kingdom	MW	Malawi
AT	Austria	GE	Georgia	MX	Mexico
AU	Australia	GN	Guinea	NE	Niger
BB	Barbados	GR	Greece	NL	Netherlands
BE	Belgium	HU	Hungary	NO	Norway
BF	Burkina Faso	IE	Ireland	NZ	New Zealand
BG	Bulgaria	IT	Italy	PL	Poland
BJ	Benin	JP	Japan	PT	Portugal
BR	Brazil	KE	Kenya	RO	Romania
BY	Belarus	KG	Kyrgyzstan	RU	Russian Federation
CA	Canada	KP	Democratic People's Republic of Korea	SD	Sudan
CF	Central African Republic	KR	Republic of Korea	SE	Sweden
CG	Congo	KZ	Kazakhstan	SG	Singapore
CH	Switzerland	LI	Liechtenstein	SI	Slovenia
CI	Côte d'Ivoire	LK	Sri Lanka	SK	Slovakia
CM	Cameroon	LR	Liberia	SN	Senegal
CN	China	LT	Lithuania	SZ	Swaziland
CS	Czechoslovakia	LU	Luxembourg	TD	Chad
CZ	Czech Republic	LV	Latvia	TG	Togo
DE	Germany	MC	Monaco	TJ	Tajikistan
DK	Denmark	MD	Republic of Moldova	TT	Trinidad and Tobago
EE	Estonia	MG	Madagascar	UA	Ukraine
ES	Spain	ML	Mali	UG	Uganda
FI	Finland	MN	Mongolia	US	United States of America
FR	France	MR	Mauritania	UZ	Uzbekistan
GA	Gabon			VN	Viet Nam

METHOD AND APPARATUS FOR RADIO TELEPHONE CALL HANDOVER IN AN UNDERGROUND RAILWAY COMMUNICATIONS SYSTEM

This invention relates to apparatus for and a method of effecting call handover in a radio telephone system in which a mobile radio moves with respect to cables which are leaky or lossy cables radiating radio fields detected by the mobile radio.

Call handover occurs when the mobile radio transfers communication from one cable to another cable. An example of such a known system is in an underground railway. Each railway station is equipped with a radio base station serving that particular railway station. Also, each base station serves an adjacent length of tunnel bore by means of a cable which extends from the base station along the tunnel bore both towards the preceding station and towards the succeeding station, in relation to the direction of travel of trains through the tunnel bore. The train carries the mobile radio, the front of the train being fitted with an antenna which makes radio communication with the cable extending along the tunnel bore. In proceeding from one railway station to the next railway station, the mobile radio must therefore transfer its communication (ie effect call handover) from one cable to another cable, this taking place approximately half-way between the railway stations where one cable ends and the next begins.

In known systems, call handover relies upon the detection by the mobile radio of the reduction of radio field as the mobile radio reaches the end of the cable. This triggers the mobile radio to search for a new channel available at the base station located at the railway station towards which the train is travelling. During call handover, an existing call will be uninterrupted only if the mobile radio can continue to communicate with the cable about to terminate. Call handover typically takes a quarter of a second or slightly more, which at 110km per hour corresponds to a distance travelled of about 30 metres. The length of train tends to shield the antenna after the front of the train has moved 10 metres or more from the end of the cable, so there will be a partial loss of call. The invention aims to provide an apparatus and a method which overcomes this problem.

According to one aspect of the invention there is provided radio telephone apparatus comprising a first cable for radiating a first radio field, a second cable for radiating a second radio field, and an attenuator for incorporation in the first cable adjacent an end thereof so that in use when a mobile radio effects call handover from the first radio field to the second radio field the reduction in strength of the first radio field resulting from the attenuator causes the mobile radio to initiate call handover and to complete call handover before the strength of the first radio field diminishes to an unusable level.

According to another aspect the invention provides radio telephone apparatus comprising a first base station, a first radiating cable extending from the first base station to a remote end, a second base station, a second radiating cable extending from the second base station and terminating in a remote end, the two remote ends being located in a transition area where a mobile radio effects call handover from the first base station to the second base station, an attenuator being incorporated in the first radiating cable adjacent the end thereof to cause the mobile radio to sense the diminution in radiated signal caused by the attenuator and thereby to commence call handover from the first base station to the second base station.

According to a yet further aspect the invention provides a method of effecting call handover of a mobile radio from a first radiating cable to a second radiating cable in a radio telephone system, comprising using an attenuator near the end of the first cable to cause a marked decrease in the strength of signal radiated by the first cable and sensing the decrease at the mobile radio to prompt the mobile radio to initiate call handover from the first cable to the second cable and to maintain communication with the first cable until handover to the second cable is accomplished.

The positioning of the attenuator defines the position at which the mobile radio commences its call handover routine. By arranging for the length of the first cable between the attenuator and the end of the first cable to be at least as much as the distance travelled by the mobile radio at its maximum possible speed, call handover without interruption is assured.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a diagram of a radio telephone system according to the invention as fitted in an underground railway, and

Figure 2 is a graph showing signal strengths detected by the mobile radio carried by the train plotted against the position of the front of the train.

Referring to Figure 1, two successive railway stations on an underground railway line are indicated at 1 and 2. The railway stations have respective base stations 3 and 4 which are similar to base stations in a cellular radio system in that each base station is linked, generally by hard wiring, to a telephone exchange. The base stations 3 and 4 have respective cable loops 5 and 6 which extend around the areas of the railway stations (eg platforms, subways and concourse) so that people equipped with mobile handsets can make and receive telephone calls through the respective base stations 3 and 4. It is envisaged that the people equipped with the necessary mobile handsets will be station personnel, security personnel or similarly authorised people, but it is possible for the radio telephone system to be accessible to members of the public provided with the usual cellular radio handsets.

The base station 3 also feeds a radiating cable 7 which extends along the tunnel bore linking the stations 1 and 2. The bore accommodates a single length of railway track 8 along which trains normally run in the same direction, indicated by arrow A. The cable 7 has a first portion 9 extending from the station 1 towards the preceding railway station and a second portion 10 extending from the station 1 towards the next station 2. Similarly, the base station 4 feeds a second cable 12 within the bore, the cable 12 having a first portion 13 extending towards the station 1 and a second portion 14 extending towards the next railway station along the line. The cables 7 and 12 are leaky or lossy in that they radiate radio fields corresponding to the electrical signals from the respective base stations 3 and 4. The cables 7 and 12 are supported by hangers on the walls of the bore so that the cables 7 and 12 extend longitudinally within the bore accommodating the

track 8 along which the trains pass (in direction A) from the station 1 to the station 2. A second tunnel bore accommodating a second railway track 15 is provided to take trains in the opposite direction B from the station 2 to the station 1.

In accordance with the invention, an attenuator 16 is incorporated in the first cable adjacent its end 17. In practice, the end section of the cable 7, ie the length between the attenuator 16 and the extreme end 17 may be an inferior cable with greater loss than the remaining main section between the base station 3 and the attenuator 16. The attenuator 16 is a resistive network. The second cable 12 has an end 18 at a position corresponding substantially to the position of the attenuator 16 so that the first and second cables 7 and 12 extend beside one another over an overlapping length of 20 metres corresponding to the length of the end section of the first cable 7.

A train travelling along the railway track 8 is equipped with a mobile radio and has, on the front of the train, an antenna which detects the radio field set up by the nearby cable 7 or 12. As the train proceeds from the railway station 1 to the railway station 2, the strength of the first radio field radiated from the cable 7 (and consequently the magnitude of the signal detected by the mobile radio) will gradually decrease as indicated at 20 in Figure 2. When the front end of the train passes the attenuator 16, the signal strength will drop sharply as indicated at 22. This sharp drop in the radio signal from the cable 7 is chosen to pass through the roaming threshold T1, ie the magnitude of received signal strength below which the mobile radio commences its routine to initiate call handover to another base station. As the train proceeds towards the next railway station 2, the strength of signal received from the first cable continues to decrease, passing eventually through the usable signal threshold T2 below which the signal is likely to be too weak to be usable.

Once the train has passed the position corresponding to the attenuator 16, the received signal strength 23 of the second radio field from the cable 12 will be sufficiently strong, ie its magnitude will be in excess of the roaming threshold T1 as indicated at 24. Hence, the mobile radio on the train will establish contact with the second radio field well before the signal strength of the first radio field passes below the usable signal threshold T2.

This ensures that the mobile radio effects call handover onto the second radiating cable 12 before leaving the transition area defined by the overlapping lengths of cables 7 and 12. This overlapping length is chosen to ensure that handover occurs within the overlapping length at the maximum speed of the train.

A similar arrangement is provided beside the railway track 15, where an attenuator 25 is incorporated near the end of a radiating cable 26 fed from the base station 4. In this case call handover is from the cable 26 to a cable 27 connected to the base station 3. Important features of the radio telephone apparatus are:

1. The attenuator is selected to provide a defined signal reduction which ensures that the radio will be triggered to register.
2. The section of radiating cable from the attenuator to the cable end provides satisfactory radio coverage for the period of registration.
3. The zone of extended coverage provided by the end section of the cable is predictable and thereby reliable when compared to the otherwise uncertain "free space" case.

Using this method the following requirements are met:-

1. The signals between base stations remain isolated so that channel management is not degraded.
2. The cost is not adversely affected since the attenuator replaces a cable terminator.

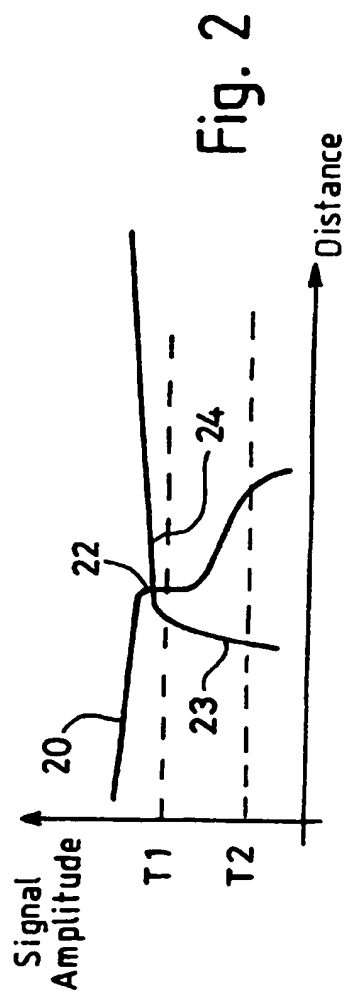
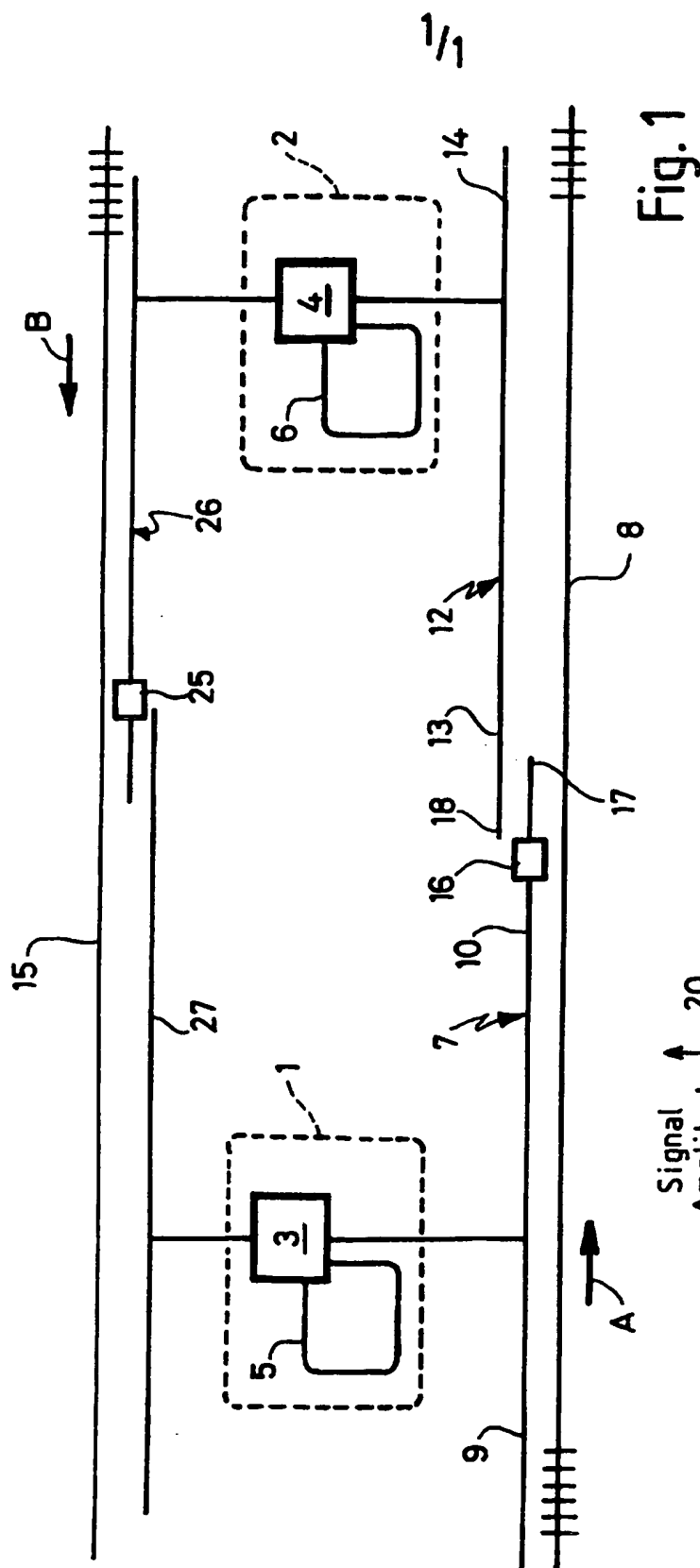
CLAIMS

1. Radio telephone apparatus comprising a first cable for radiating a first radio field, a second cable for radiating a second radio field, and an attenuator for incorporation in the first cable adjacent an end thereof so that in use when a mobile radio effects call handover from the first radio field to the second radio field the reduction in strength of the first radio field resulting from the attenuator causes the mobile radio to initiate call handover and to complete call handover before the strength of the first radio field diminishes to an unusable level.
2. Apparatus according to claim 1, wherein the attenuator is a resistive network.
3. Apparatus according to claim 1 or 2, wherein the first cable comprises a main section extending up to the attenuator and a second section extending from the attenuator to the end of the first cable, the second section having higher loss characteristics than the main section.
4. Apparatus according to claim 3, wherein the second section has a length between 15 metres and 25 metres.
5. Apparatus according to claim 4, wherein the second section has a length of the order of 20 metres.
6. Radio telephone apparatus comprising a first base station, a first radiating cable extending from the first base station to a remote end, a second base station, a second radiating cable extending from the second base station and terminating in a remote end, the two remote ends being located in a transition area where a mobile radio effects call handover from the first base station to the second base station, an attenuator being incorporated in the first radiating cable adjacent the end thereof to cause the mobile radio

to sense the diminution in the radiated signal caused by the attenuator and thereby to commence call handover from the first base station to the second base station.

7. Apparatus according to claim 6 and fitted in an underground railway system, the first and second base stations being located at respective railway stations and the radiating cables extending along a tunnel bore interconnecting the railway stations.

8. A method of effecting call handover of a mobile radio from the first radiating cable to a second radiating cable in a radio telephone system, comprising using an attenuator near the end of the first cable to cause a marked decrease in the strength of signal radiated by the first cable and sensing the decrease at the mobile radio to prompt the mobile radio to initiate call handover from the first cable to the second cable and to maintain communication with the first cable until handover to the second cable is accomplished.



INTERNATIONAL SEARCH REPORT

Intern. Application No
PCT/GB 96/02590

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 H04B5/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 011, no. 292 (E-543), 19 September 1987 & JP 62 091026 A (NEC CORP), 25 April 1987, see abstract	1,6,8
A	--- PATENT ABSTRACTS OF JAPAN vol. 016, no. 392 (E-1251), 20 August 1992 & JP 04 127726 A (NEC CORP), 28 April 1992, see abstract	1,6,8
A	--- PATENT ABSTRACTS OF JAPAN vol. 009, no. 140 (E-321), 14 June 1985 & JP 60 022834 A (MITSUBISHI DENKI KK), 5 February 1985, see abstract	1,6,8
	--- -/-	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

G document member of the same patent family

Date of the actual completion of the international search

30 January 1997

Date of mailing of the international search report

13.02.97

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl,
Fax (+ 31-70) 340-3016

Authorized officer

Lydon, M

INTERNATIONAL SEARCH REPORT

Internat'l Application No
PCT/GB 96/02590

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 012, no. 111 (E-598), 8 April 1988 & JP 62 242427 A (NEC CORP), 23 October 1987, see abstract ---	1,6,8
A	DE 24 02 600 A (LICENTIA GMBH) 24 July 1975 see page 5, line 3 - page 6, line 5 see page 7, line 11 - page 8, line 10 see page 10, line 2 - page 11, line 18 see figures 1,2 -----	1,6,8

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 96/02590

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE-A-2402600	24-07-75	NONE	